Quantifying surface emissions of methanol using observations from the Tropospheric Emission Spectrometer

Kelley C. Wells, **Dylan B. Millet**, Karen E. Cady-Pereira, Mark W. Shephard, Ming Luo, Daven K. Henze

dbm@umn.edu
www.atmoschem.umn.edu

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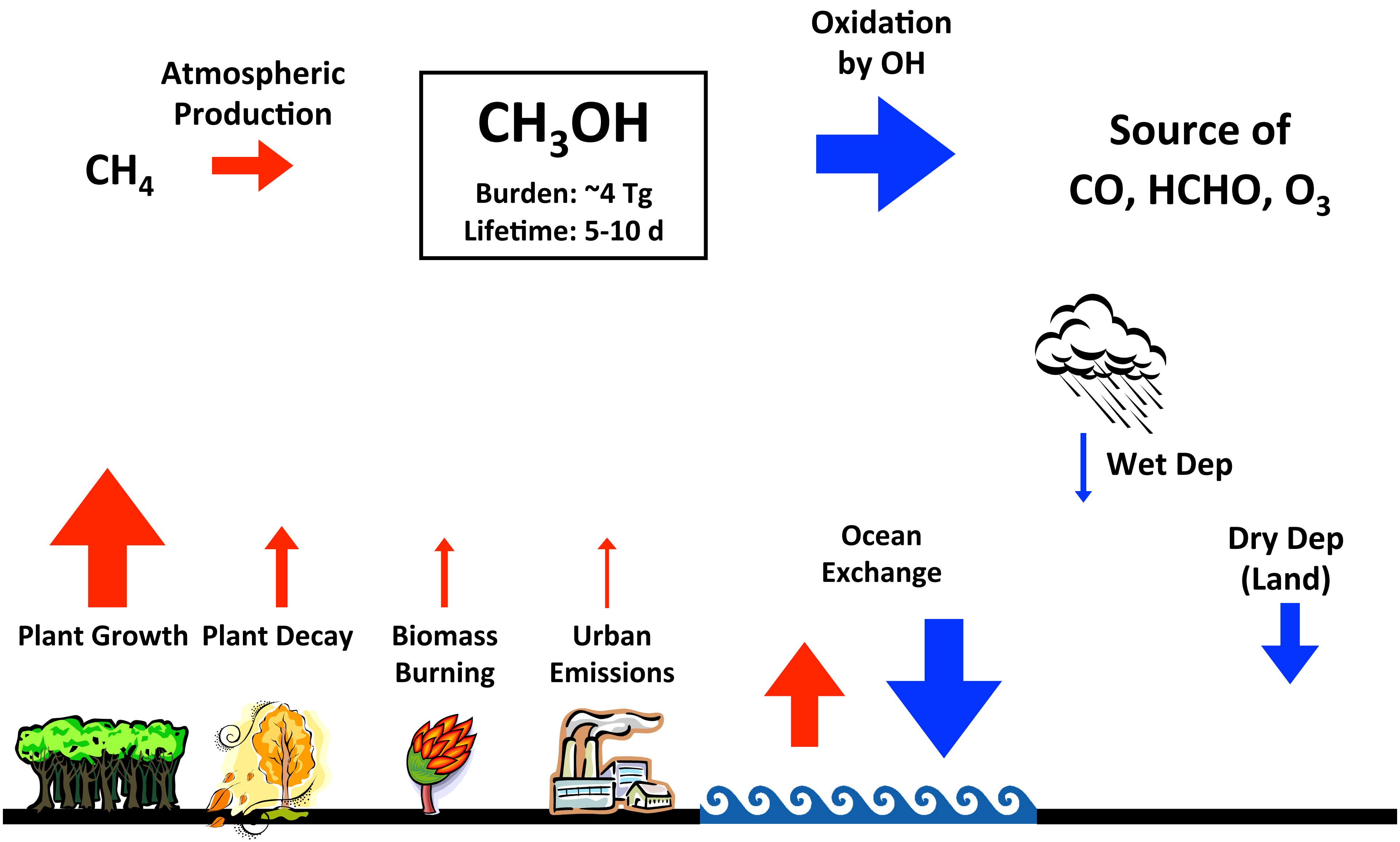
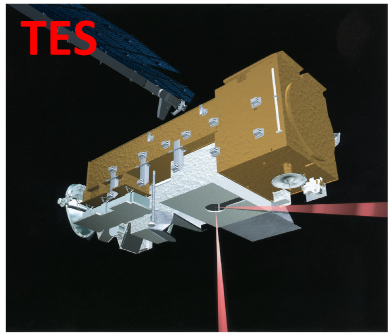
October 3, 2012

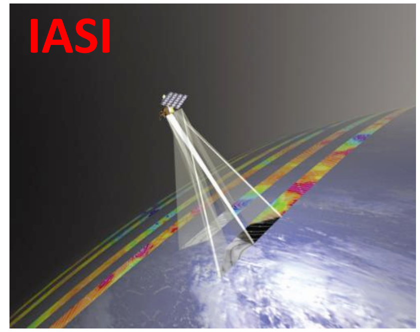
METHANOL IS THE MOST ABUNDANT NON-METHANE ORGANIC COMPOUND IN THE ATMOSPHERE



METHANOL MEASUREMENTS FROM SPACE:
thermal emission IR spectrometry

- Launched 07/2004
- 0.06 cm^{-1} spectral resolution
- 5 × 8 km^2 footprint
- 16-day repeat cycle





- Launched 10/2006
- 0.5 cm^{-1} spectral resolution
- 12 km footprint diameter
- 2× daily global coverage

***For both instruments, usually max ~ 1 DOF** → can't retrieve vertical profile*

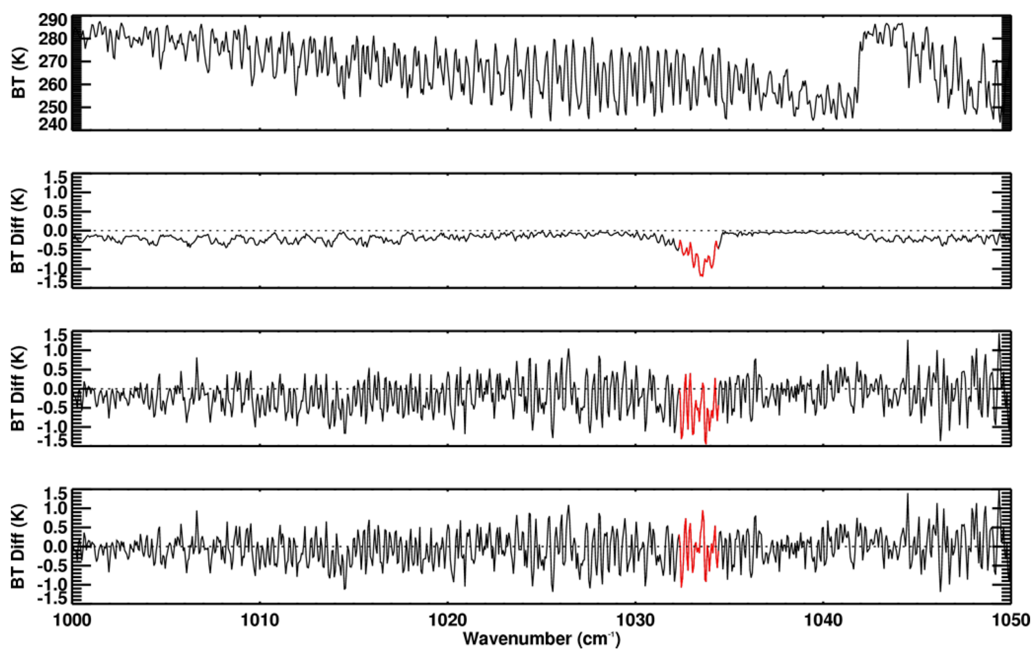
Sample methanol measurement from TES

Observed Brightness Temp

Methanol signal

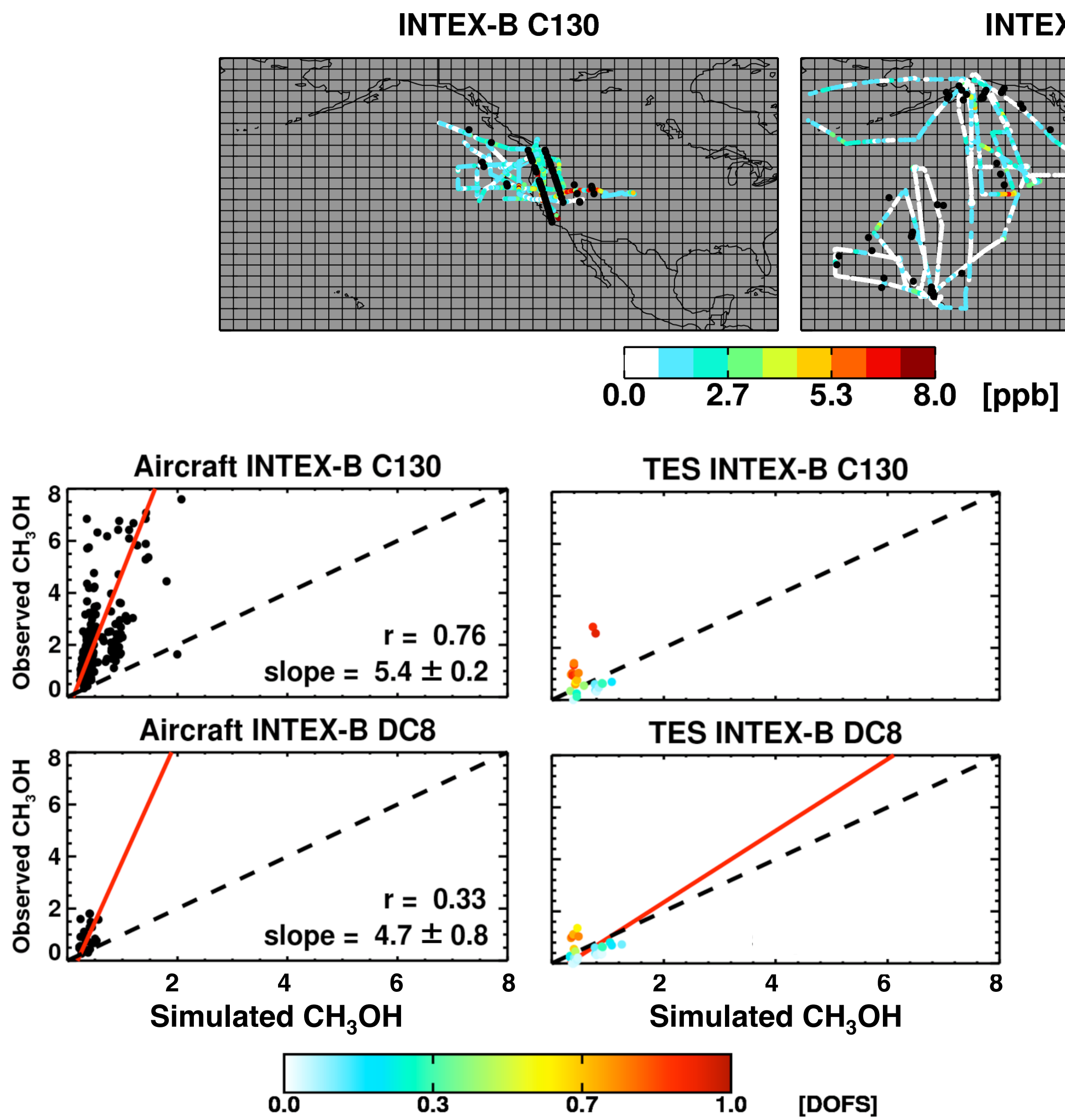
Residuals (before methanol retrieval)

Residuals (after methanol retrieval)



AIRCRAFT OBSERVATIONS TO TEST METHANOL RETRIEVAL

Use GEOS-Chem model as transfer standard to compare satellite vs aircraft data



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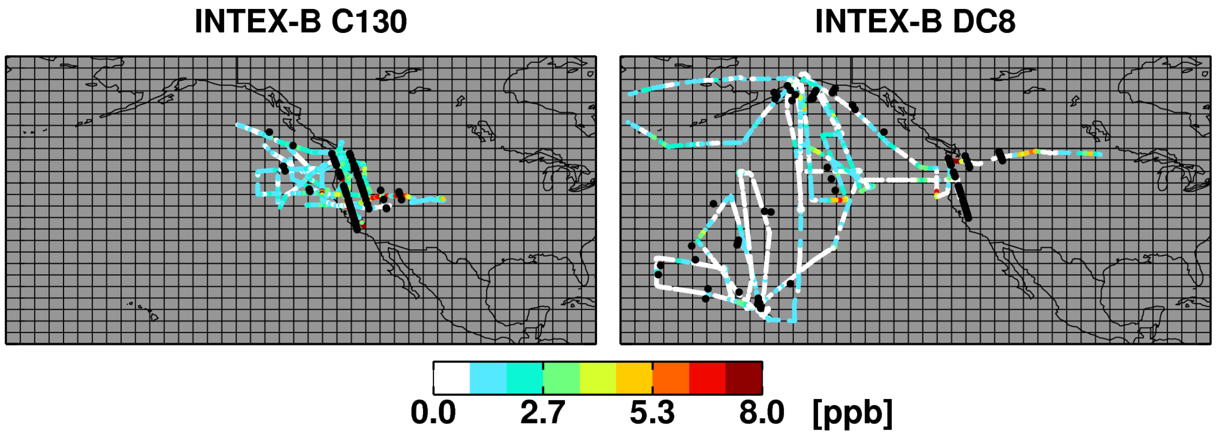

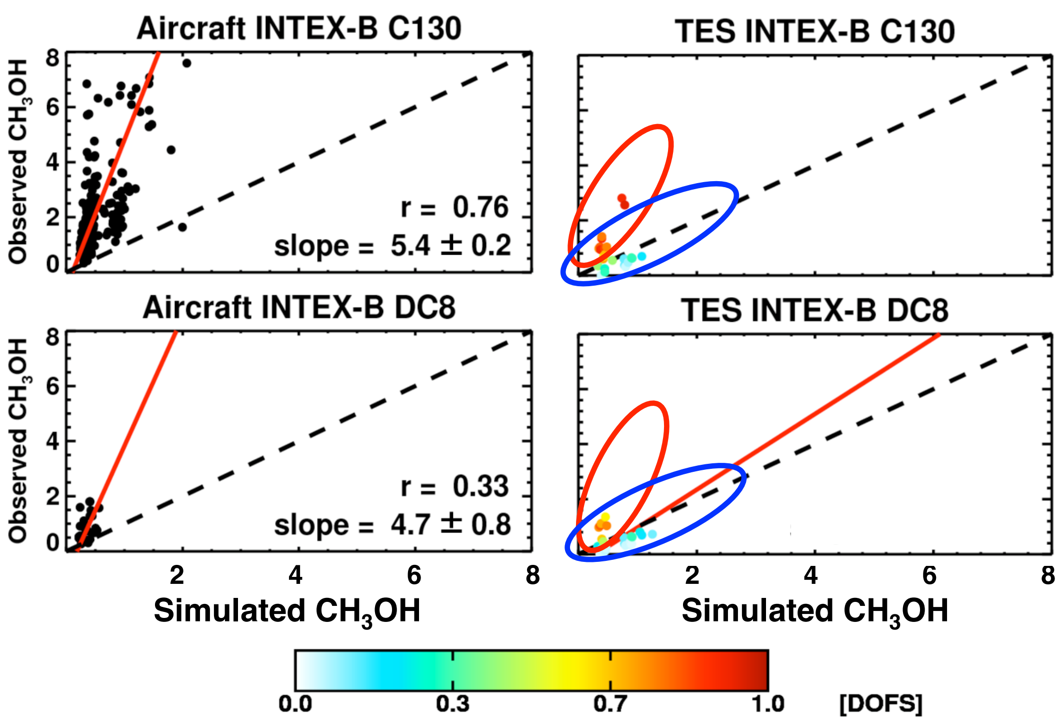

2 populations!
Retrievals with low DOFS contaminated by initial guess

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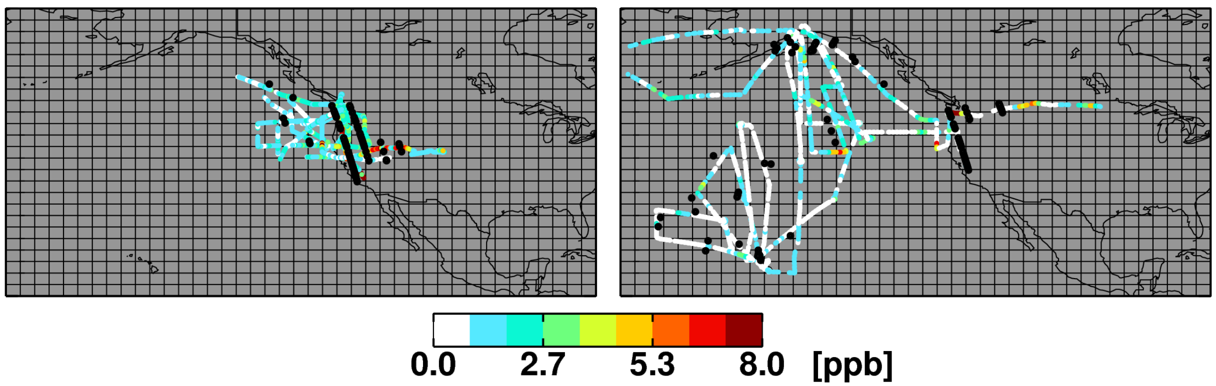
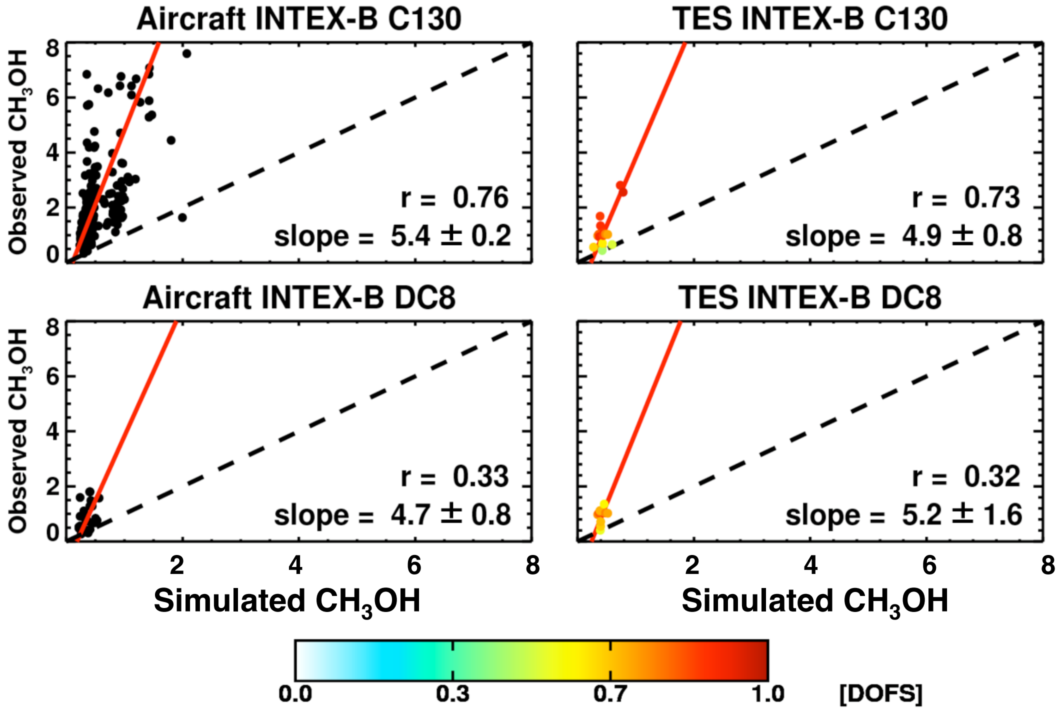
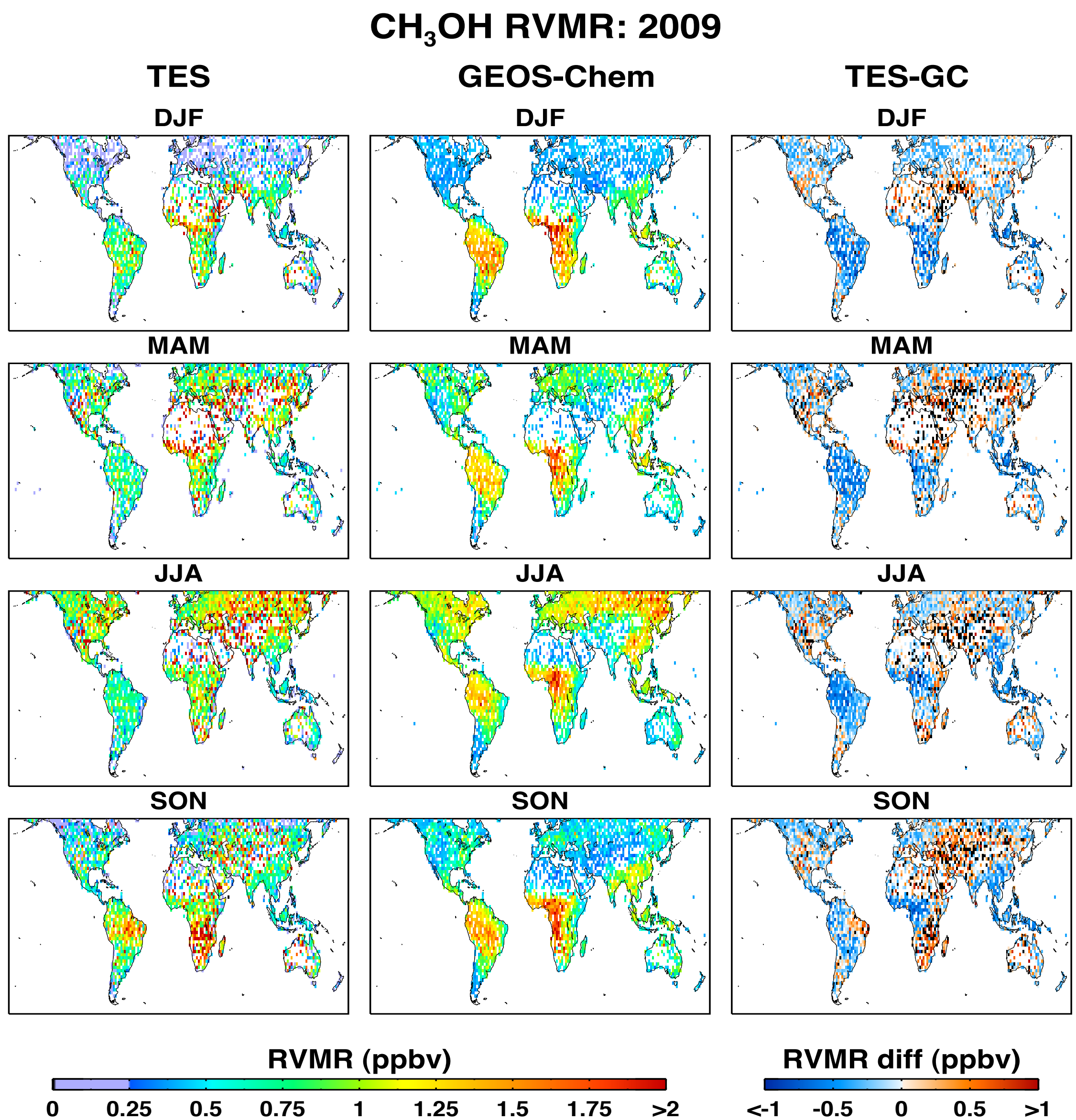




For DOFS > 0.5, TES retrievals consistent with aircraft data

Both datasets reveal model underestimate in western US

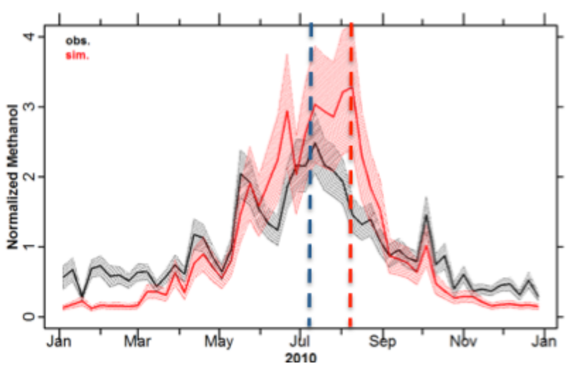
EMPLOY SATELLITE DATA TO TEST UNDERSTANDING OF METHANOL SOURCES



SATELLITE DATA REVEAL SEASONAL BIAS IN MODEL

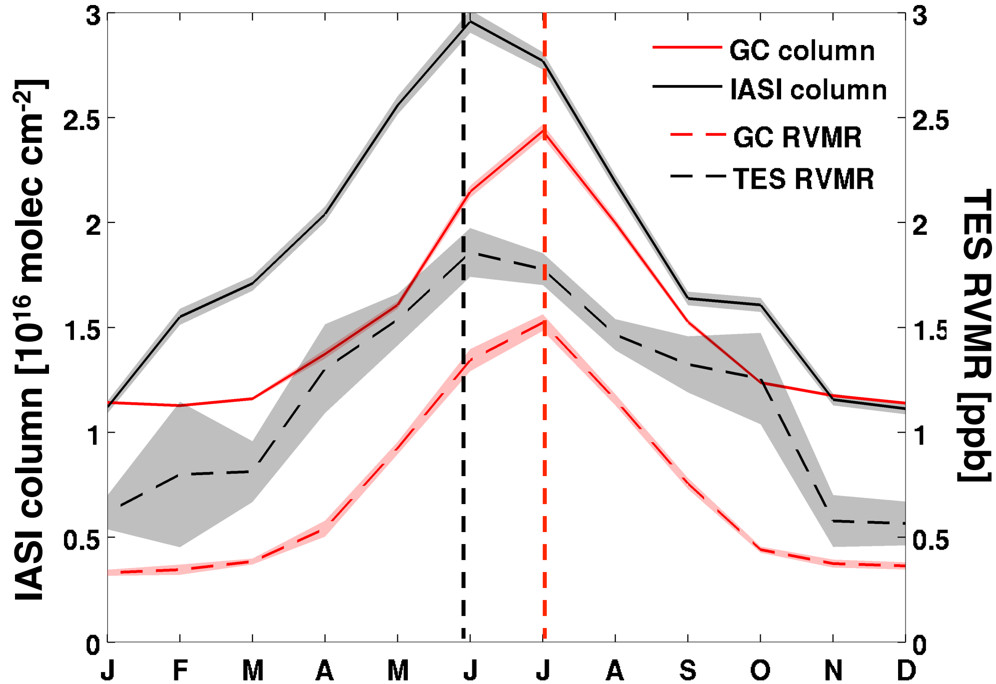
~1 month offset in seasonal peak for temperate ecosystems

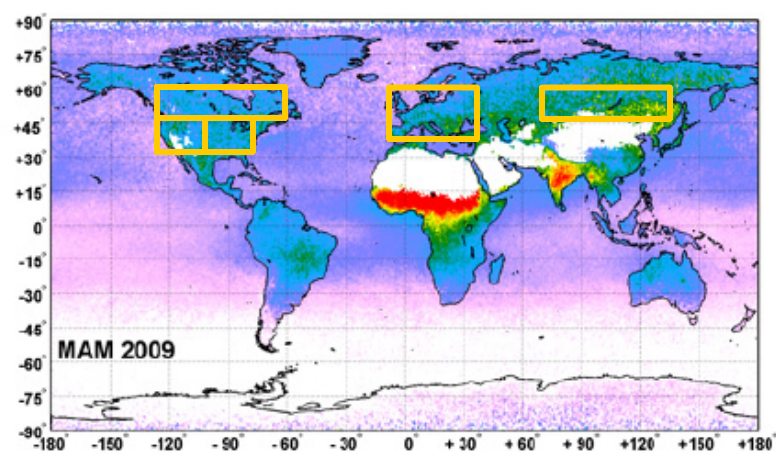
confirms findings from UMN Tall Tower



Red: GEOS-Chem **Black: Observed**

Red: GEOS-Chem **Black: Satellite**





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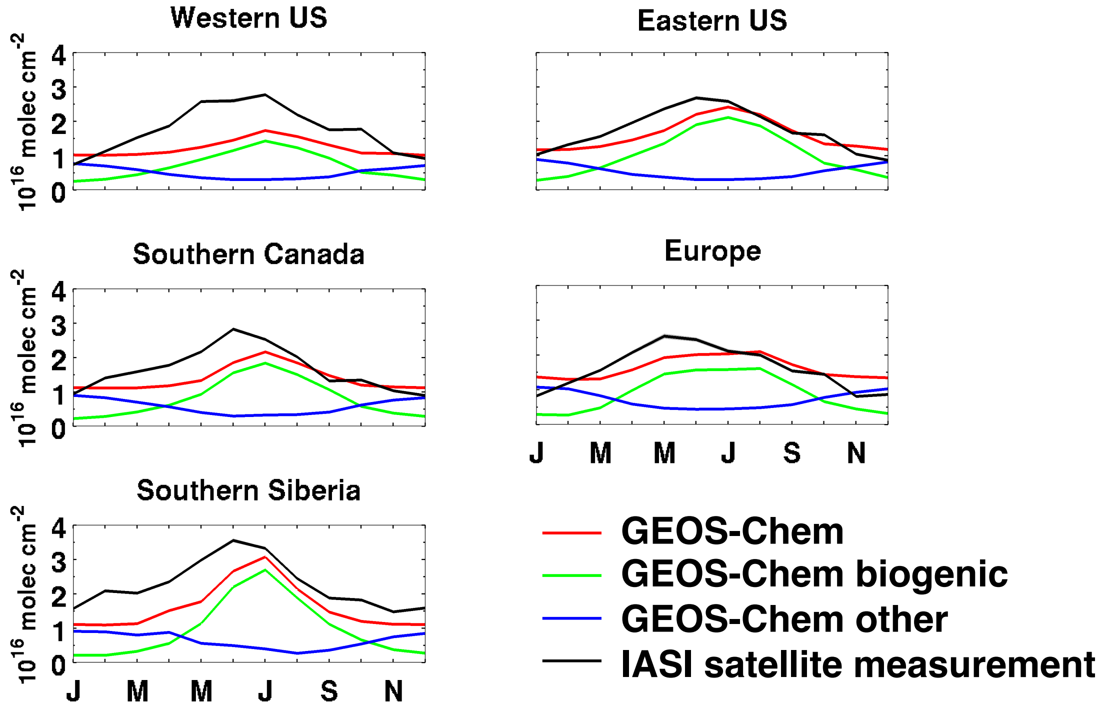
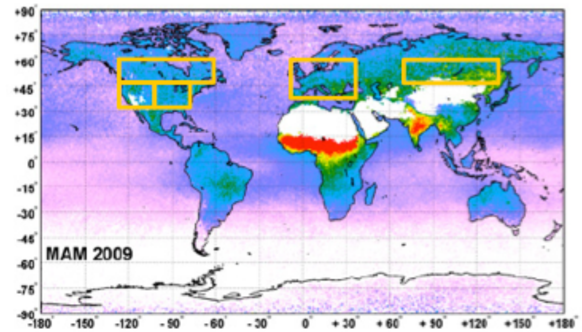
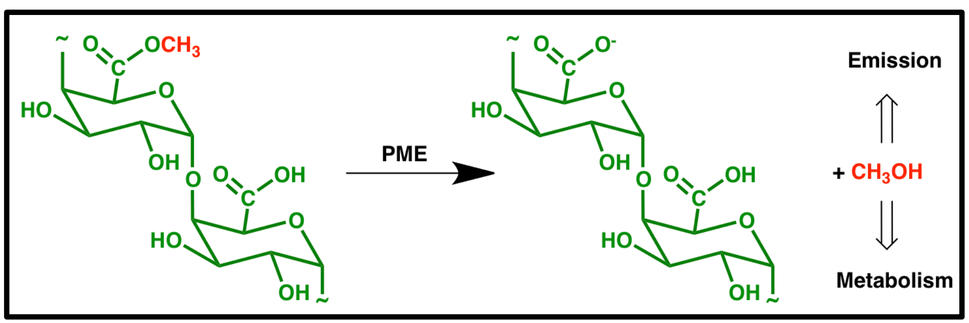


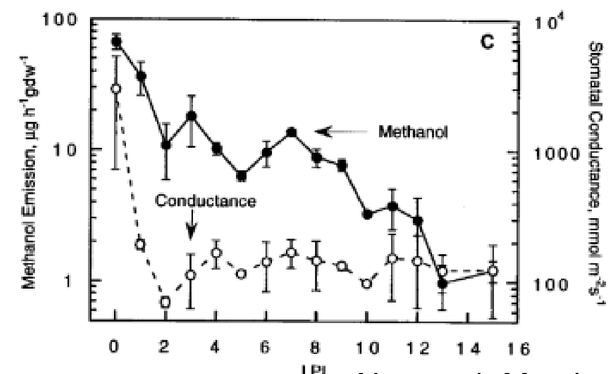


Biogenic source drives seasonality

BIAS IMPLIES EMISSION UNDERESTIMATE FOR NEW LEAVES



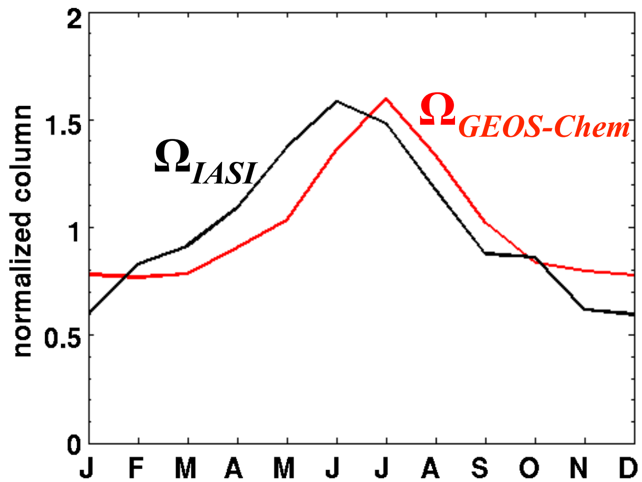
Leaf level emissions versus leaf age

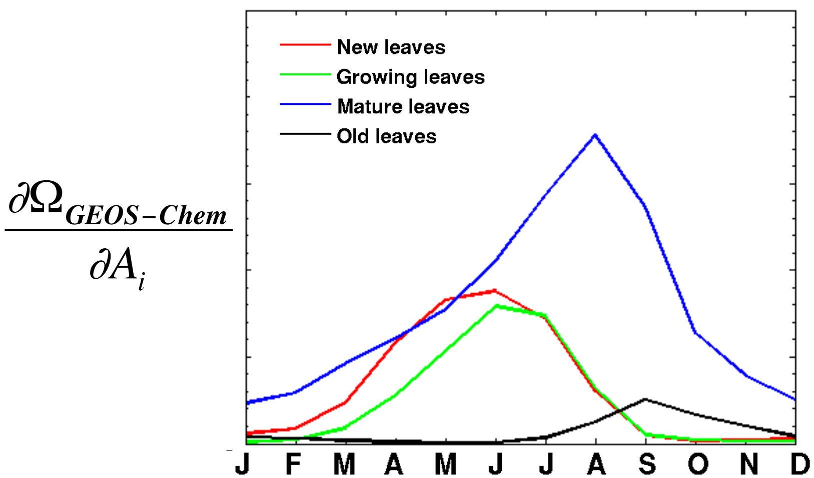


Nemecek-Marshall et al. [1995]

SPACE-BASED CONSTRAINTS ON LEAF AGE EMISSION RATES

Optimize leaf age emission rates on basis of satellite data





$$\Omega_{IASI} = \Omega_{GEOS-Chem} + \sum_{i=1}^{4} \beta_i \frac{\partial \Omega_{GEOS-Chem}}{\partial A_i}$$

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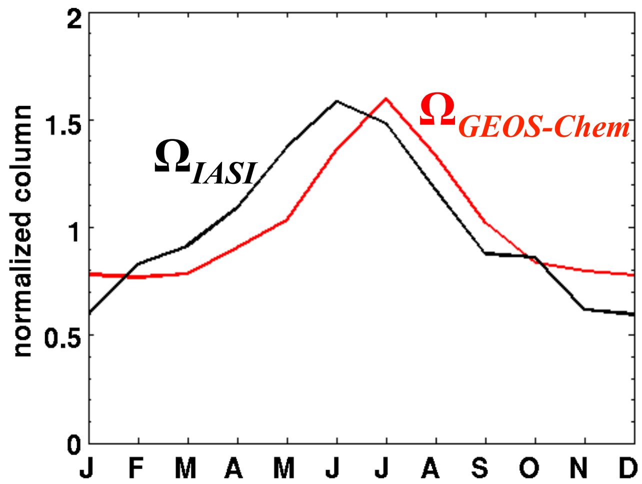
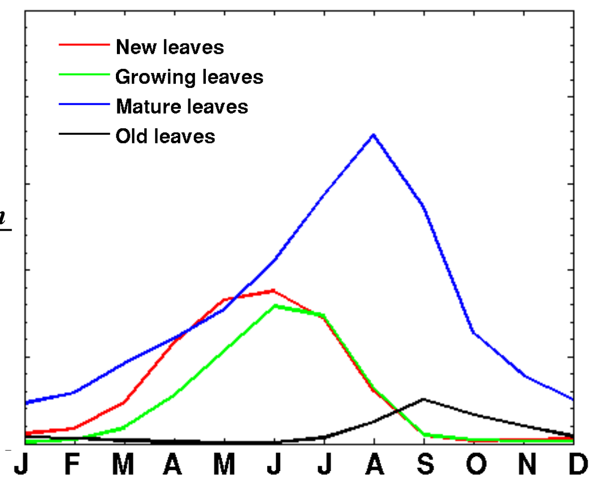
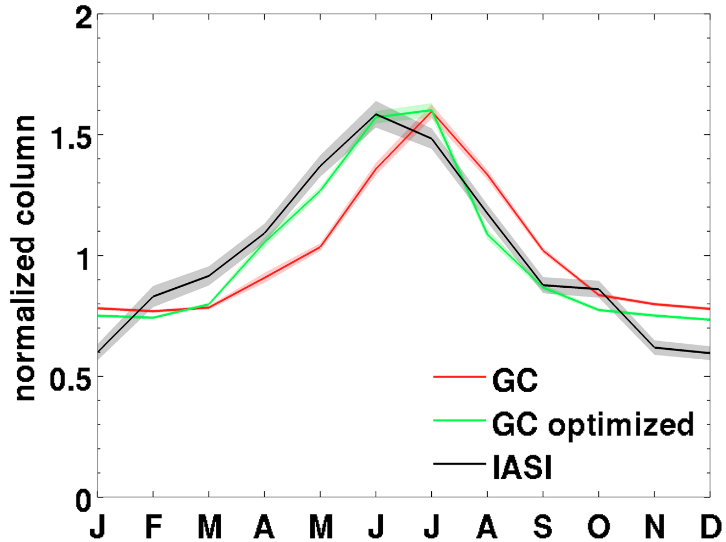


$$\frac{\partial \Omega_{GEOS-Chem}}{\partial A_i}$$



$$\Omega_{IASI} = \Omega_{GEOS-Chem} + \sum_{i=1}^{4} \beta_i \frac{\partial \Omega_{GEOS-Chem}}{\partial A_i}$$

Global average: Temperate regions

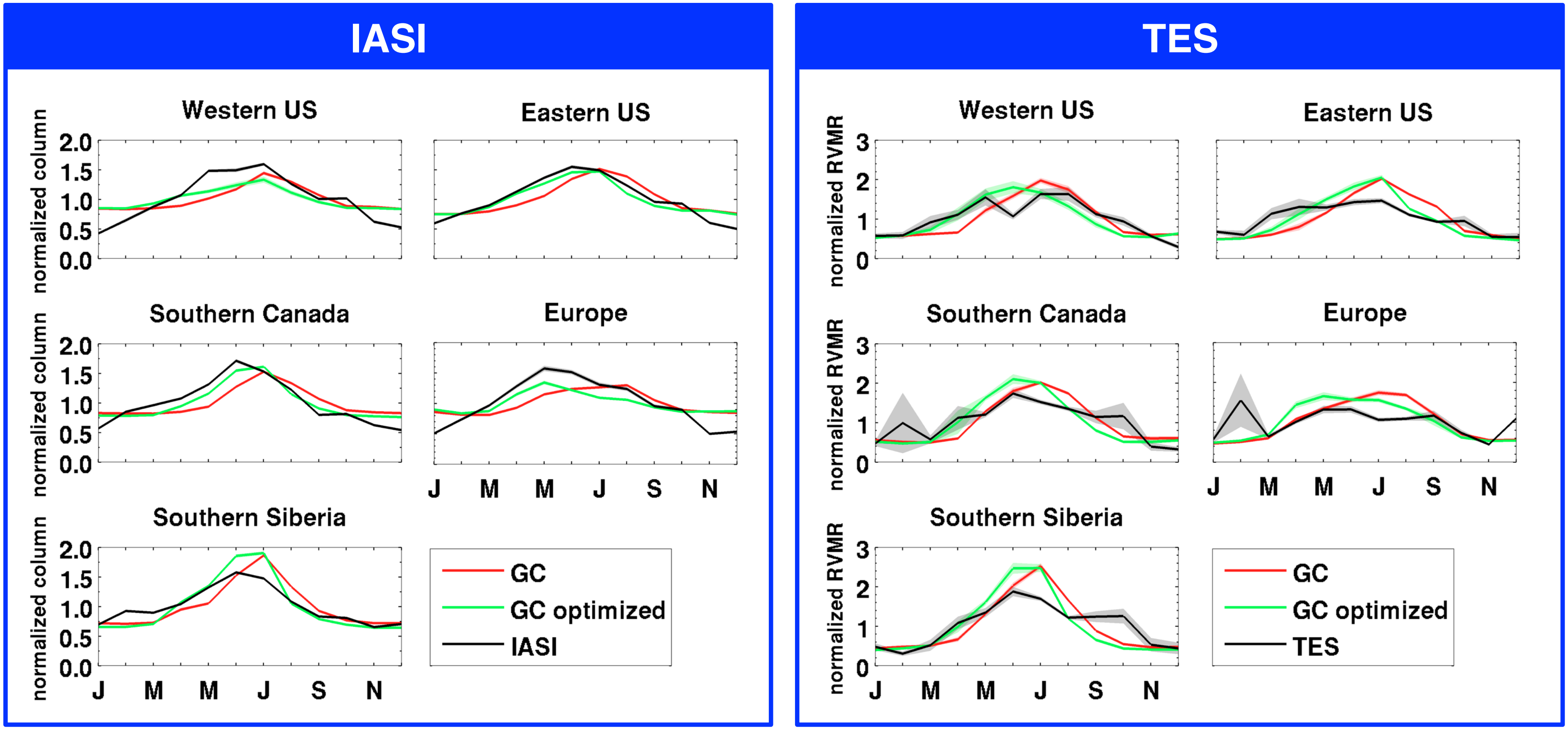


	GC	GC opt
A_{new}	3.0	11.0
$A_{growing}$	2.6	0.26
A_{mature}	0.85	0.12
A_{old}	1.0	3.0

***Also set γ_{LAI} = 0.5 for expanding canopies**

SPACE-BASED CONSTRAINTS ON LEAF AGE EMISSION RATES

Optimized leaf age parameters better capture seasonality in atmospheric methanol as observed by IASI, TES & ground-based data



Pronounced photochemical role for methanol early in growing season
when methanol emissions high, but isoprene emissions still relatively low

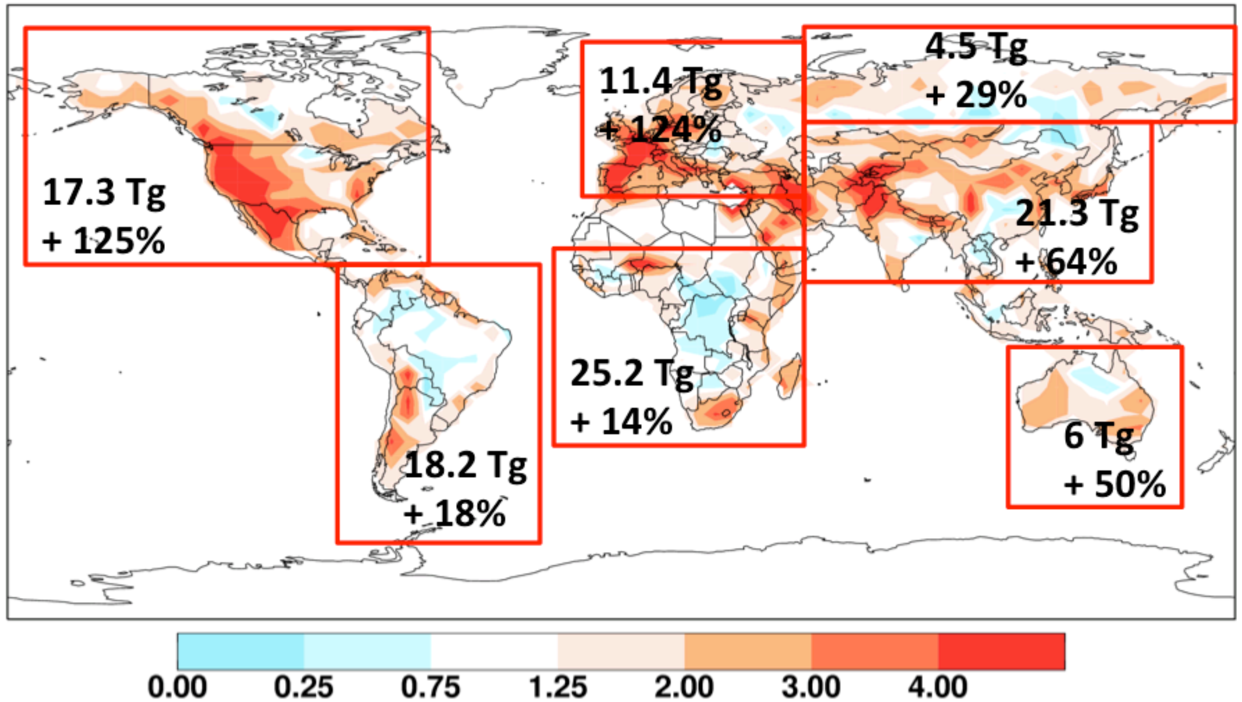
Wells et al., ACP (2012)

APPLY GEOS-CHEM ADJOINT + TES DATA TO CONSTRAIN GLOBAL METHANOL EMISSIONS

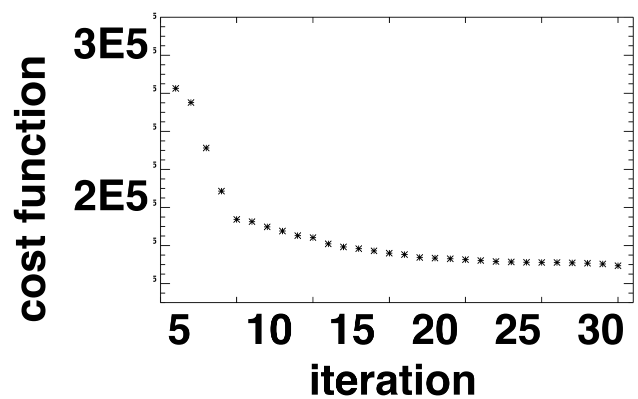
A posteriori scale factors and emissions from global adjoint optimization:

TES data imply 20% increase in global source

But significant regional adjustments

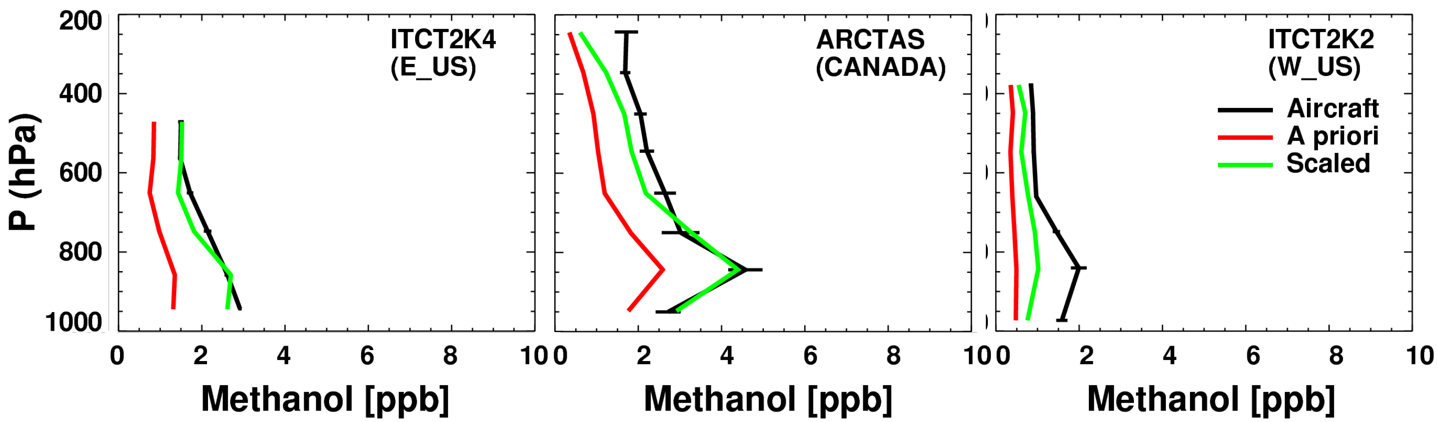


Cost function reduced ~35%

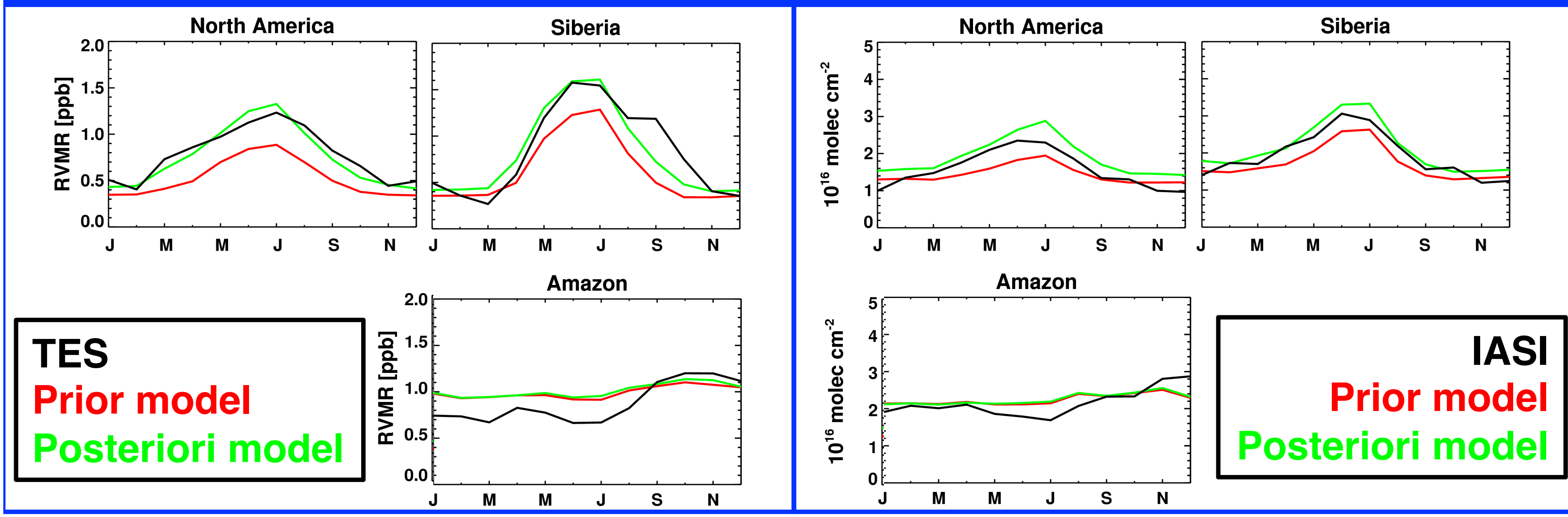


A POSTERIORI MODEL COMPARISON WITH OBSERVATIONS

TES-based optimization improves model agreement with aircraft data in all cases



Improved model agreement with TES and IASI for extra-tropical regions…

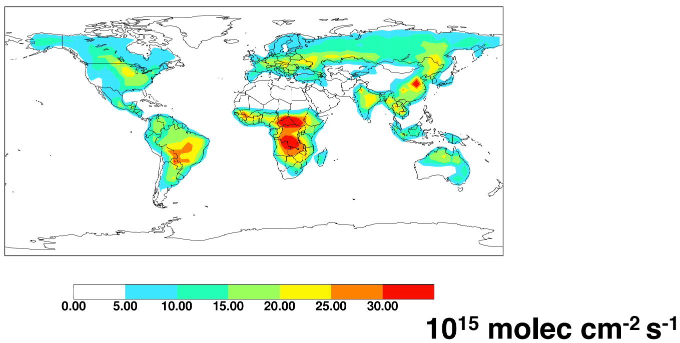


…BUT SEASONALITY NOT WELL CAPTURED IN TROPICS

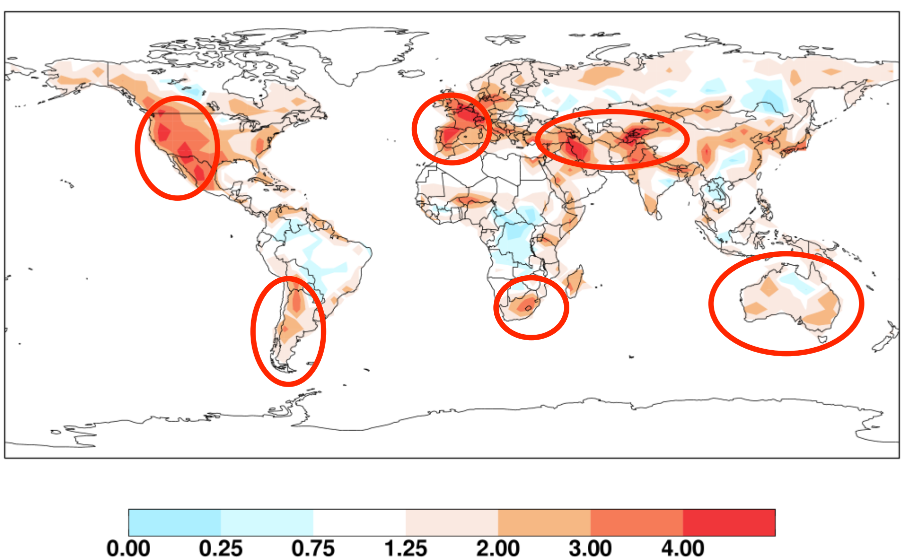
NEXT: INTERPRET INVERSION RESULTS IN TERMS OF EMISSIONS FROM VARIOUS PLANT TYPES

Spatial bias → model underestimate for certain plant functional types?

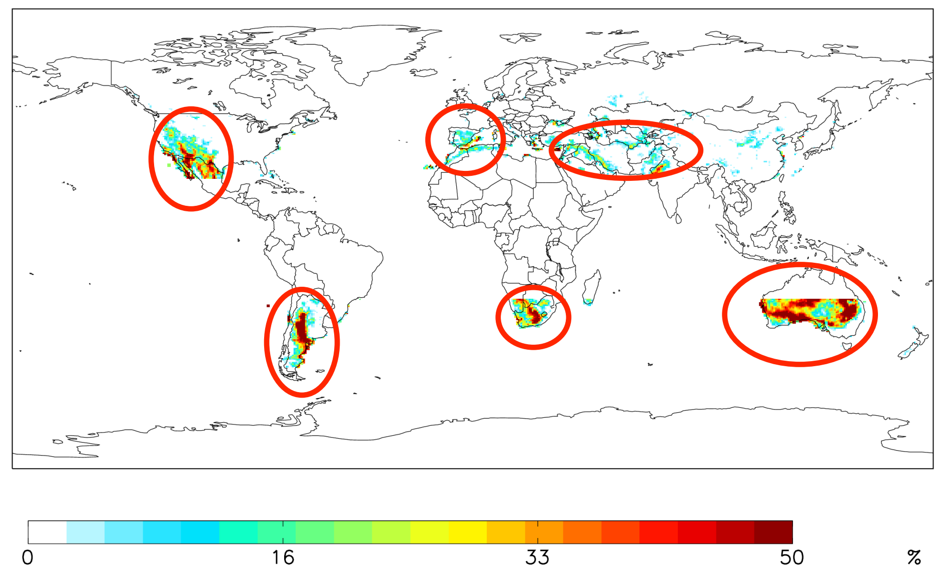
A priori methanol emissions



Total Scale Factor



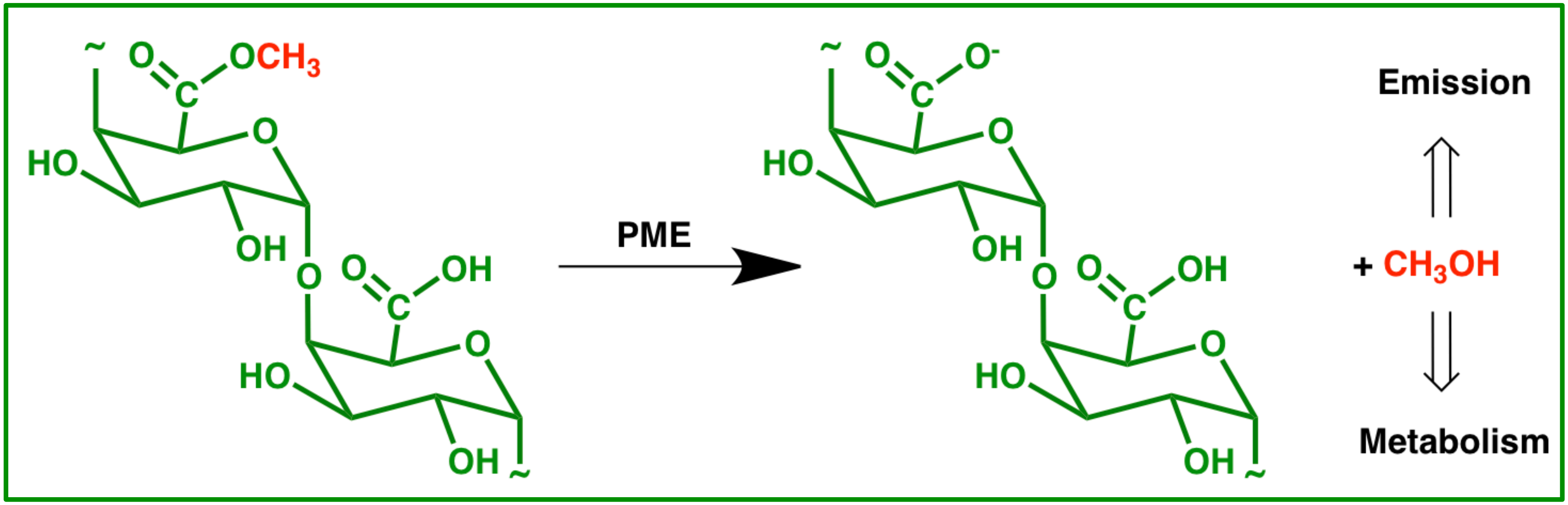
Broadleaf Deciduous Temperate Shrub



→ Underestimate of emissions from shrubs?

METHANOL: PRODUCED IN PLANTS DURING CELL WALL EXPANSION

Pectin demethylation:



Fall & Benson, 1993

Most (all?) plants emit methanol

Broadleaf trees

Needleleaf trees

Crops & grasses

Shrubs

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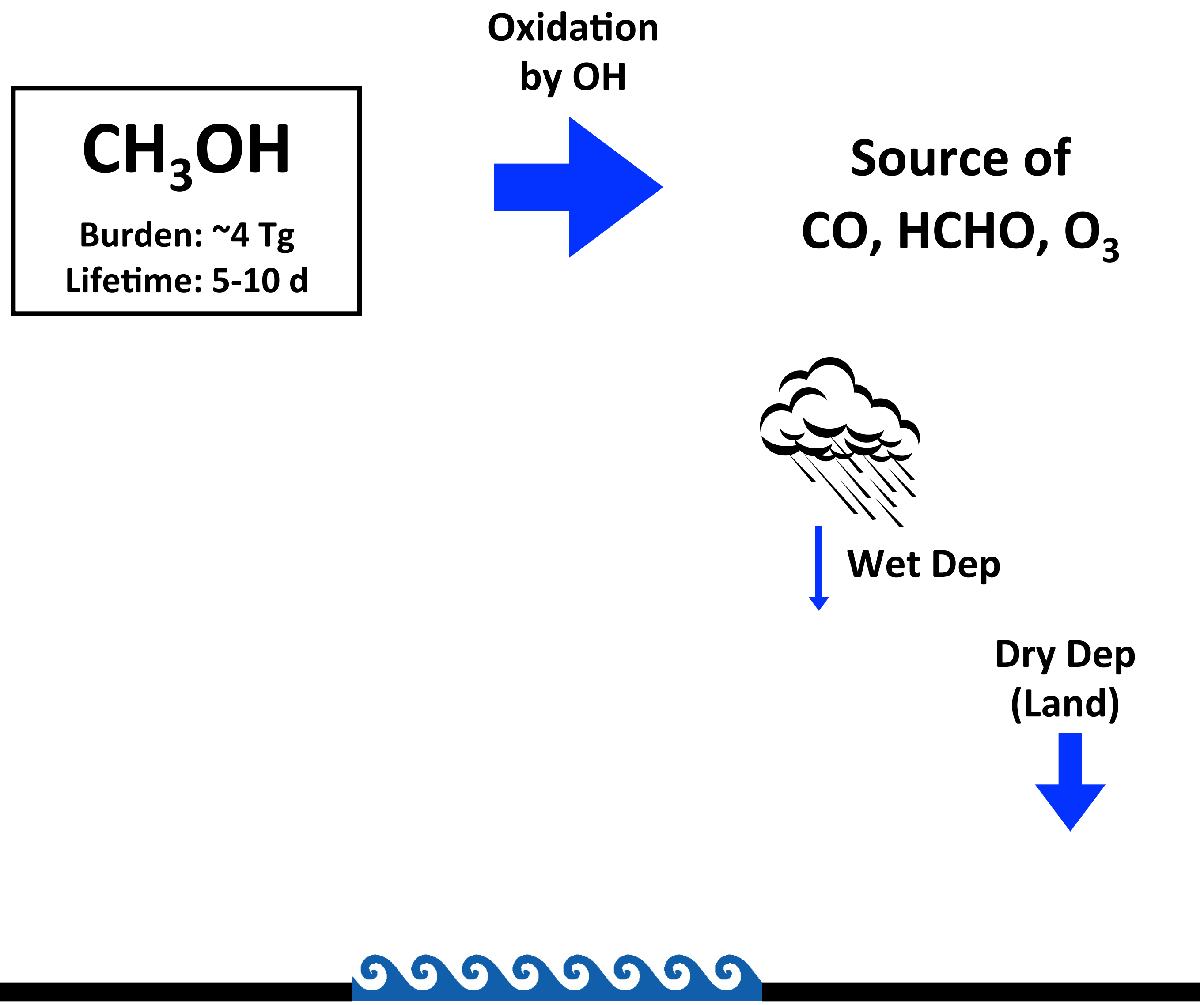
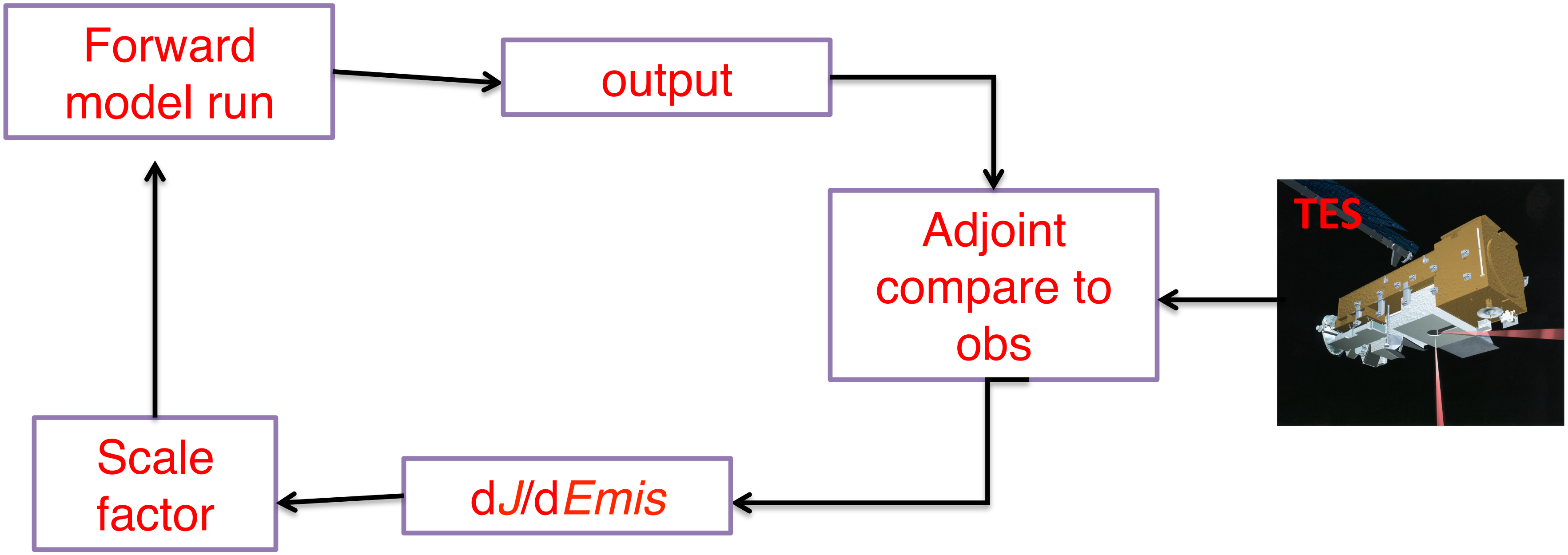


NEXT: APPLY GEOS-CHEM ADJOINT + TES DATA TO CONSTRAIN METHANOL EMISSIONS FOR DIFFERENT PLANT TYPES



J = cost function **Adjoint calculates dJ/dx**

observational mapper (model to obs space)

model concentrations

regularization parameter

a priori error

$$J(x) = \frac{1}{2}[\mathrm{y} - \mathrm{H}(\mathrm{c})]^{\mathrm{T}} S_y{}^{-1}[\mathrm{y} - \mathrm{H}(\mathrm{c})] + \frac{\gamma}{2}[x - x_a]^T S_a{}^{-1}[x - x_a]$$

observations

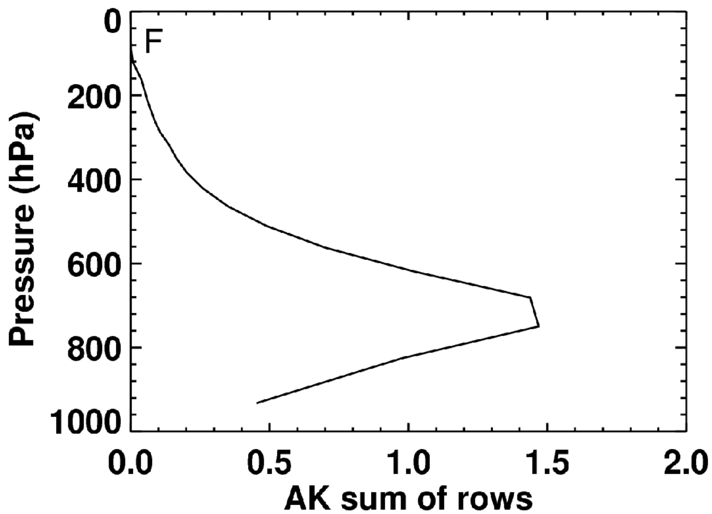
observational error

emissions scale factor

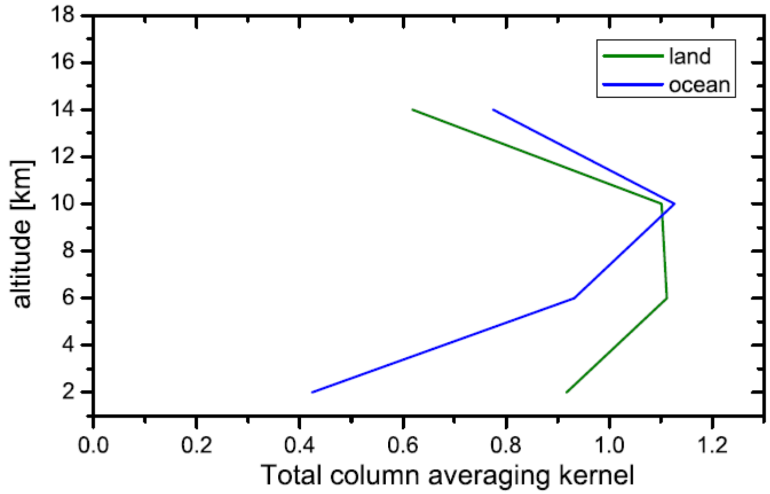
a priori

VERTICAL SENSITIVITY OF MEASUREMENT

TES Peak sensitivity ~1-3 km
16-day repeat time



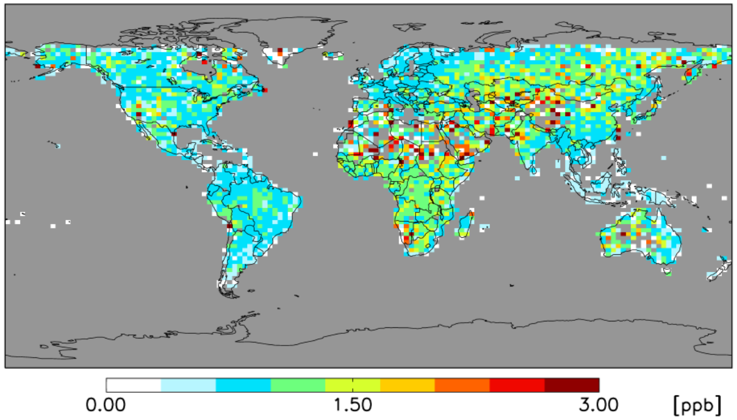
IASI Peak sensitivity ~5-10 km
2× daily global coverage



For both, usually max ~ 1 DOF

→ can't retrieve vertical profile

TES RVMR (ppb)



IASI vertical column (molec/cm²)